TOWARDS A BETTER QUANTIFICATION OF CROPLANDS EXTENT AND MANAGEMENT CONTRIBUTION TO CARBON CYCLING

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ABSTRACT
The development of agriculture responding to increasing demand for food raises the question of the role of cultivated land in relation to carbon sources and sinks, their spatial patterns and temporal variability. For the first time we couple a global terrestrial biosphere model (ORCHIDEE[a]), itself part of an Earth System Model, to a crop model (STICS[c]) via a flexible and efficient coupling scheme. The simulated carbon and water fluxes strongly respond to the climate interannual variability associated with severe productivity drops for the 1976 and 2003 European drought events.

INTRODUCTION
Previous simulation studies of the terrestrial biosphere relied mainly on undisturbed ecosystems. A new generation of global biosphere models now includes realistic parameterizations of croplands and land management, to address the specific questions related to human impact on terrestrial ecosystems. For example, irrigation and harvest operations imply changes in soil-vegetation-atmosphere fluxes as well as in soil properties. Thus there was a crucial need to account for the effect of the functioning of agro-ecosystems and for the strong impact of population demand for food products on the carbon, water and energy budgets. Only few modeling studies have started to investigate this effect at global and regional scale [*Bondeau & Smith, in prep., Kucharik & Brye,* 2003]

METHODOLOGY
The ORCHIDEE model [*Krinner et al.,* 2005] used to represent croplands using two herbaceous Plant Functional Types (PFTs) (C3 and C4 photosynthetic pathways). However, these PFTs had a longer seasonal cycle with a smaller amplitude and were less productive than actual croplands. In addition, they did not respond to management practices. These limitations lead to the choice of coupling ORCHIDEE to a generic crop model, STICS, for quantitative studies of the role of agriculture in biogeochemical cycles and its contribution to regional climate change.

We developed a new flexible and efficient coupling scheme, benefiting from INRA's agronomical expertise. STICS *(Brisson et al., 2002)* is a point model already able to simulate the growth and yield of standard temperate crops at the field scale, but still being tested for tropical crops. The spatialization of STICS and its input datasets was a necessary step towards the coupling with ORCHIDEE driven by gridded climate, soil and vegetation forcings. ORCHIDEE-STICS is presently operational for corn, wheat and soybean, representing respectively a C4 PFT, a winter-type and a summer-type C3. Different variables either poorly simulated by ORCHIDEE for crops (Leaf Area Index (LAI), vegetation height, root profile) or specific to STICS (nitrogen limitation index, irrigation) are assimilated into ORCHIDEE and integrate information such as sowing and harvest dates as well as hybrid selection.

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[a] ORCHIDEE : ORganizing Carbon and Hydrology In Dynamic EcosystEms
[c] STICS : Simulateur mulTIdisciplinaire pour les Cultures Standard

The coupled model is run for the northern hemisphere temperate crops over the last 35-year period at different resolutions depending on domain size. Site simulations driven by local forcing are evaluated against Eddy-covariance data and other field measurements. Regional simulations are compared with satellite biophysical observations and crop yield statistics.

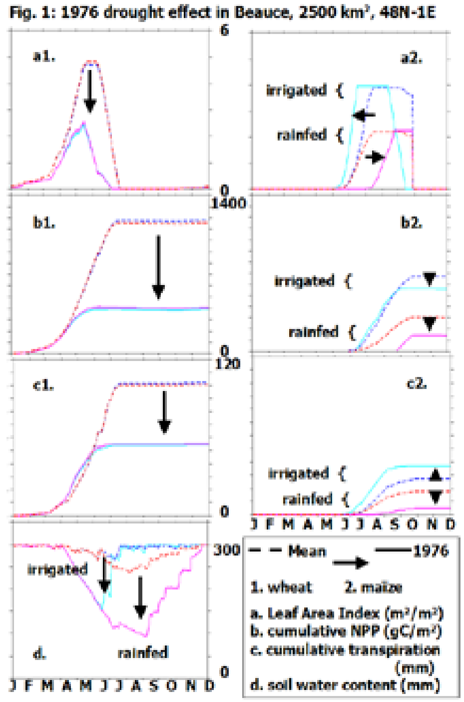
RESULTS AND DISCUSSION

We found a clear improvement of modelled ecosystem productivity and fluxes seasonality [*Gervois et al.*, 2004, *De Noblet-Ducoudré et al.*, 2004]. Simulations over the past century in Europe reproduce the tripling of wheat and maïze yields and confirm the driving effects of management on agro-ecosystems productivity as compared to the effect of climate change and atmospheric CO_2 alone.

The analysis for the 1976 and 2003 extreme droughts in Europe, of a set of model simulations (with or without croplands, variable management etc.) driven by climate reconstructions, show a strong crop Net Primary Productivity (NPP) reduction as compared respectively to the reference periods 1972-1979 and 1995-2004. Associated with this productivity drop, the seasonal cycle of LAI, transpiration and soil water content undergoes heavy changes during the 1976 drought year in terms of amplitude and timing. Wheat and maïze respond quite differently to this climate anomaly according to their specific phenology and water-use efficiency leading to different impacts on carbon and water budgets. See example for a highly agricultural French region in Fig. 1.

We analyse the spatial pattern and temporal development of these 1976 and 2003 anomalies, compare the two drought events with each other and quantify the impact of these extreme climate conditions on carbon sequestration in temperate agricultural ecosystems. We discuss the overall negative Net Ecosystem Exchange (NEE) anomaly in the drought years as compared to normal years. A dampening in the variability, attributed to adaptative practices (irrigation) is found as compared to the case where croplands are modelled as natural grasslands. Modelled interannual NPP and NEE variability are also compared with national and sub-national level reports of yield, inverse atmospheric estimates and results from other bottom-up approaches.

Fig. 1: 1976 drought effect in Beauce, 2500 km², 48N-1E



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